TECHNICAL MANUSCRIPT 103

AIR-BORNE INFECTION IN THE LABORATORY

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AIR-BORNE INFECTION IN THE LABORATORY

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ABSTRACT

Air-Borne infection in the laboratory is discussed in connection with the diagnostic laboratory, including frequency of various diseases, how infection occurs, and precautionary measures. Emphasis is placed upon the importance of tuberculosis, brucellosis, and viral hepatitis. It is urged that diagnostic laboratories undertake practical investigations of laboratory microbiological safety, and that they investigate and report their laboratory illnesses to the Committee on Laboratory Infections and Accidents of the American Public Health Association.

I. INTRODUCTION

The significance of air-borne infection among personnel studying microorganisms highly infectious for man has been systematically explored in the U.S. Army Biological Laboratories and summarized in various publications.[1,2] For those interested in all aspects of microbiological safety, the most thorough recent review is that by Chatigny.[3] However, an equal amount of systematic attention has not been given to diagnostic and public health laboratories, where research with infectious agents is secondary to the principal mission. This report will examine the role of air-borne occupational infection in laboratories not primarily concerned with research on highly infectious materials.

II. HOW INFECTION OCCURS

The first important point to recognize is that the infectious dose most often arises in an aerosol at the laboratory bench during common microbiological techniques (Table I).

This is why a definite act or accident, such as an aspiration, injection, cut, spill, or bite, can be associated with only 14 to 35 per cent of reported laboratory-acquired infections.[5] Recently, the importance of the routine laboratory procedure as a cause of infection was reaffirmed during an elaborate analysis made of all accidents in our laboratories from 1959 through 1962. There were 1171 minor accidents reported and 47 major accidents. The latter included all infections whether or not there was loss of time, and all mechanical or chemical injuries that caused the employee to be unable to report for duty on the following day. All other accidents were considered to be minor. One of the results of this study is presented in Table II, which shows the ratio of major accidents to minor accidents.

The lower ratios are considered indicative of the more hazardous situations. Although it is necessary to keep in mind the variable quality of accident reporting, and the unusual emphasis upon safety in our laboratories, nevertheless it is significant that handling infected eggs and diluting and plating cultures were the most hazardous under our conditions of experimentation. Production of minor microbial aerosols characterizes these techniques. Whether the person becomes infected then depends upon the factors contributing to the variable status of the host-parasite relationship.

TABLE I. AEROSOLS PRODUCED BY COMMON MICROBIOLOGICAL TECHNIQUES

Laboratory Operation	Colonies Obtained on Air Sampler Plate	
	Minimum	Maximum
Inserting cold loop into broth culture	0	0.22
Agglutination, slide drop technique (one slide)	0	0.66
Pipetting 10 ml of culture into 50-ml tube	0.1	1.2
Allowing one drop *S. indica* culture to fall three inches onto:		
Stainless steel	0.2	4.7
Painted wood	0.01	0.6
Towel wet with 5 per cent phenol	0	0.5
Pan of 5 per cent phenol	0	0
Removing culture from vaccine bottle with syringe needle	0	10
Removing dry cotton plug from shaken culture flask	0	16
Injecting guinea pig intraperitoneally with 0.5 ml of culture	15	16
Streaking agar plate with loopful broth culture	0	20
Inserting hot loop into broth culture	0.7	25
Opening screw-cap bottle of culture (Tomlinson[4])	1	50
Streaking rough agar plate with loopful broth culture	7	73
Opening lyophilized ampoule by breaking tip	4	256

TABLE II. RATIO OF MAJOR ACCIDENTS TO MINOR ACCIDENTS IN THE LABORATORY

Laboratory Procedure or Activity	Ratio
Handling eggs	1:3
Diluting, plating	1:7
Transporting, packaging infectious materials	1:12
Handling bulk infectious material	1:15
Handling heavy laboratory apparatus	1:16
Chemical titrations	1:25
Decontaminating and repairing rooms	1:28
Animal care	1:48
Exposing, injecting, autopsying animals	1:106
Aerobiological experiments	1:116

TABLE III. FREQUENCY OF LABORATORY-ACQUIRED INFECTIONS

Diseases and Number of Cases Reported					
U.S. Public Health Service Labs. 1910-1950[a][17]		Phillips[17]		Sulkin and Pike[16]	
Q fever	78	Tuberculosis	173	Brucellosis	224
Typhus	47	Q fever	96	Tuberculosis	153
Tularemia	33	Brucellosis	26	Q fever	104
R.M.S.F.	28	Psittacosis	25	Hepatitis	75
Psittacosis	11	Tularemia	14	Tularemia	65
Brucellosis	10	Diphtheria	12	Typhus	64
Others	24	Toxoplasmosis	11	Typhoid	58
		Typhoid	8	Streptococcal Infections	55
		Vaccinia	6	Coccidioidomycosis	49
		Echo virus	6	Psittacosis	44

a. Primarily research units.[17]

Next in importance is the disease that may be contracted. Table III lists laboratory-acquired diseases according to their frequency.

The compilation includes reports from research institutions and therefore is not completely applicable to the problems of the diagnostic laboratory. The frequency of Q fever infection results from the activities of a very few research units and therefore has little application to the usual diagnostic laboratory. The impact of tuberculosis or chronic brucellosis upon the life of a young man or young woman has made me an uncompromising advocate for installation of a protective ventilated cabinet for routine work with their agents. That these two are the most common dangers to the medical laboratory worker is also the view of the National Association for the Prevention of Tuberculosis (England) and of the American Public Health Association Committee on Laboratory Infections and Accidents.

Viral hepatitis heads the list of viral diseases contracted in the diagnostic Laboratory. It can be a distressingly long illness. It seems to be principally a contact infection. However, the virus is excreted in the stool. For this reason I am interested in the possible epidemiological role of the flush toilet.[6] According to the referenced study, the mass median diameter of all bacterial-laden particles aerosolized during flushing of the toilet was 2.33 microns. These particles are well suited for inhalation. There are other serious viral diseases the technician may acquire, such as monkey B virus infection and Russian spring-summer encephalitis, but these are rare. Fortunately, few diagnostic laboratories handle Coccidioides immitis. Almost all other possible infections can be treated adequately with antibiotics.

Each piece of equipment carries its own index of hazard as a producer of potentially infectious areosol. The most commonly used probably is the centrifuge. Table IV shows the results of examination of various procedures associated with the centrifuge.[7]

Studies elsewhere demonstrate that fluid can escape during centrifuging from containers with screw-on caps and rubber washers, because some fluid becomes trapped in the thread of the screw-caps. When spun in an angle centrifuge, this fluid forms a spray that extends over an area about 7 feet in diameter.[8] Some Swedish laboratories safeguard against microbial aerosolization from the centrifuge by operating it in a ventilated ultraviolet-irradiated cabinet (Figure 1).[9] The shaking machine for tuberculosis sputum has not been studied to determine the extent to which it is an aerosol producer, but there is no doubt that its operation is undesirable from a safety viewpoint.

TABLE IV. HAZARDS OF CENTRIFUGING PROCEDURES

Procedure or Occurrence	Average number of clumps of organisms recovered by air sampler
Filling centrifuge tubes, 10 ml of culture	0.6
Filling centrifuge tubes, 30 ml of culture	1.2
Removing cotton plugs after centrifuging	2.3
Removing rubber caps after centrifuging	0.2
Removing supernatant from 30 ml of centrifuged culture	0.3
Centrifuging two capped steel tubes from which supernatant has been twice decanted, leaving trace of culture on lip of tube	2.0
Resuspending cells from 30 ml of culture	4.5
Decanting supernatant into flask	17.6
Breakage of tube, culture staying in cup	4.0
Breakage of tube, culture spilling into centrifuge	1183.0

Diagnostically infected animals present less of a microbiological safety problem than does work at the laboratory bench. Nonetheless, cross-infection between inoculated and control animals housed in the same cage shows that infectious material is loose in the cage. Among diseases infectious for man there are surprisingly few infections of this sort, except when the animal receives a respiratory challenge by exposing the head or whole body to the microbial aerosol. Animal cross-infection indicates there may be danger for the technician. Precautions are particularly advisable with tuberculosis-infected guinea pigs.[10] Solid-sided cages, or these irradiated with ultraviolet light, can be used, or some system of ventilated housing.[11] More studies are needed under actual laboratory conditions to evaluate the extent of the danger to the technician and animal caretaker.

The hyodermic syringe, in addition to being a common means of accidental self-injection, presents a number of aerosol-creating situations, such as during accidents when the needle is withdrawn from a rubber stoppered vial, when air is exhausted from the syringe, and when it is used to homogenize clots and sputum.

Lyophilization, opening ampoules of lyophilized cultures, and associated accidents produce manual contamination and infective aerosols.[12] The most commonly required safety practice is to surround the ampoule with a disinfectant-moistened pledget while it is being broken. Other techniques producing significant aerosols involve shaking, grinding, bubbling, and homogenizing.

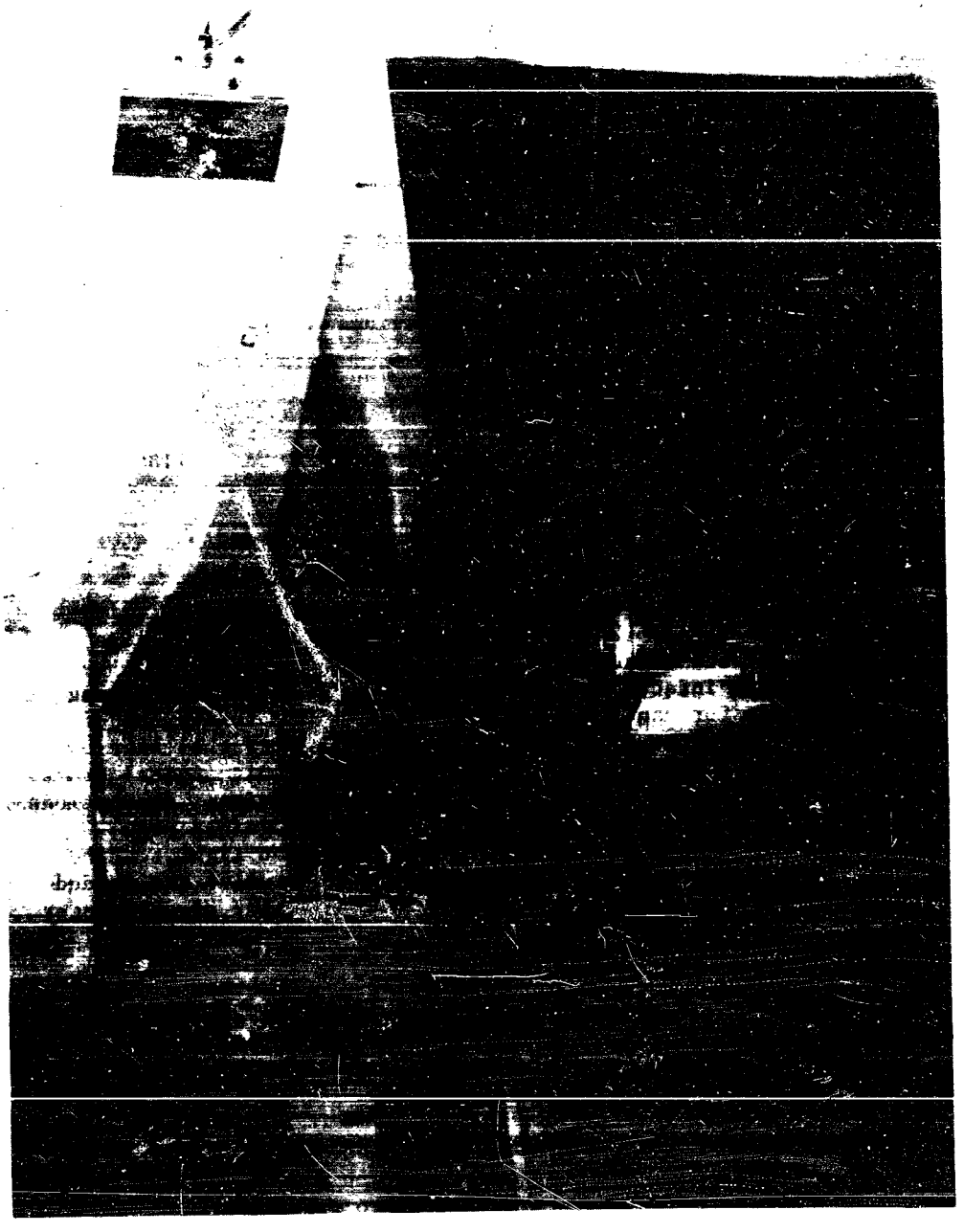

Figure 1. Centrifuge Cabinet. (FD Neg C-7158)

III. ADMINISTRATIVE ASPECTS

The administrative and budgetary status of microbiological safety in diagnostic laboratories is much the same as was the status of the industrial eye protection and other industrial safety programs many years ago. Just as in each business enterprise there are rarely any dramatic instances of the value of eye protection, likewise no one can see any dramatic results after installing microbiological safety equipment. All that is evident are the disadvantages. To convince personnel at all levels, more studies, evaluations, practical corrective measures, alternative safer techniques,[13] and reports of laboratory infections are needed from operating laboratories.[14,15] Small developmental research grants would be helpful.

During a survey in 1951, 1342 infections were analyzed.[16] These represent only a fraction of the cases occurring. In 1959 and 1960, personal interviews at 102 laboratories in the United States and 17 foreign countries revealed that 65 laboratories recalled 426 infections, and that 73 of the 102 laboratories kept no written records of infections.

To coordinate information, the American Public Health Association has formed a Committee on Laboratory Infections and Accidents. The Chairman is Dr. S. E. Sulkin, University of Texas Southwestern Medical School, 5323 Harry Hines Boulevard, Dallas 19, Texas. Better voluntary reporting of laboratory infections to that Committee, including the findings of a thorough epidemiological investigation of each infection, would facilitate appraisal of the problem and result in broadly based realistic recommendations.

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